Consortium for
Electricity
Reliability
Technology
Solutions

Reliability Adequacy Tool for Ancillary Services

FUNCTIONAL/DESIGN SPECIFICATION AND DATA REQUIREMENTS

Version 0.91 ***- CONFIDENTIAL***
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1. INTRODUCTION

The Consortium for Electric Reliability Technology Solutions (CERTS) has been formed to perform research, develop, and commercialize new methods, tools, and technologies to protect and enhance the reliability of the U.S. electric power system under the emerging competitive electricity market structure. The members of CERTS include former Edison Technology Solutions (ETS), Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), the Power Systems Engineering Research Consortium (PSERC), and Sandia National Laboratories (SNL). Southern California Edison (SCE) acts as a CERTS Research Provider.

CERTS is developing a series of integrated computer base reliability adequacy tools that will help power system Operating Authorities (e.g. ISOs, RTOs and Security Coordinator) comply with the North American grid reliability standards. As part of the integrated approach, an Ancillary Services Performance, Tracking and Predictive Adequacy Application (ASPTP) is being developed for a Host Control Area located within the Western System Coordinating Council (WSCC).

The purpose of this document is to define the functional and design specifications for a ASPTP application for Ancillary Services such as Regulation, Operating Reserves Spinning, Operating Reserves Non-Spinning and Replacement Reserves. The functionality of this application has been identified and defined based on current market processes used to acquire Ancillary Services in California and on the reliability standards of three organizations, a) NERC and its Policy 1 and 10, which addresses generation control and ancillary services. b) The WSCC and its reliability policies and guidelines and, c) additionally, feedback from other CERTS related projects.

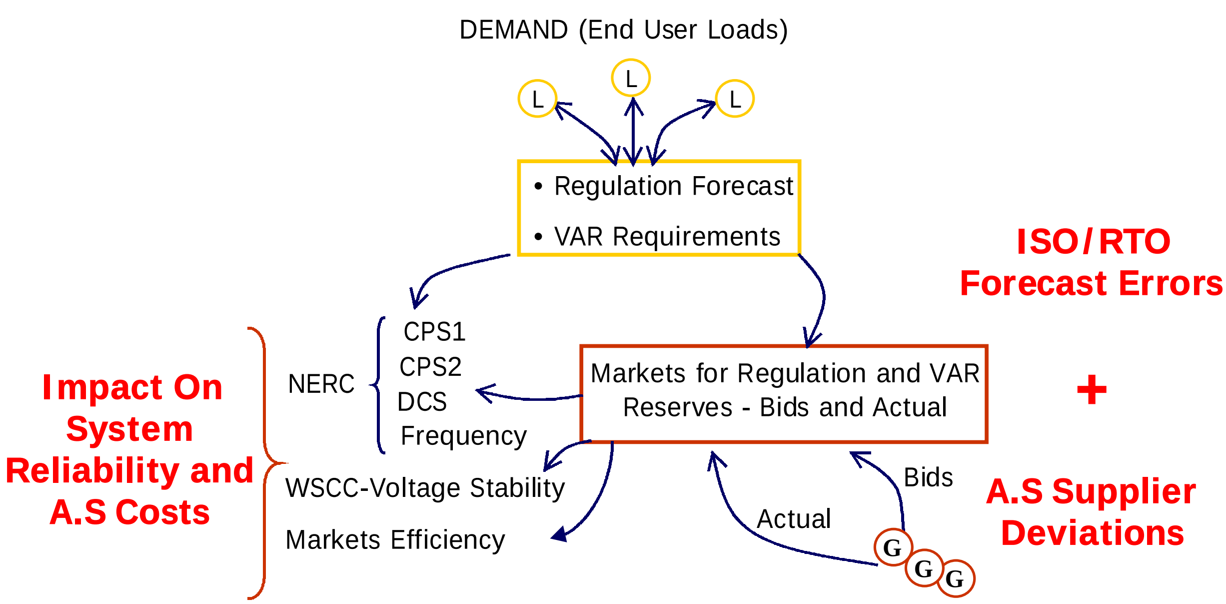
The document also describes the process to define the graphic-geographic visual components and perspectives that will allow for effective visual analysis to respond to the new operational challenges raised by competitive and deregulated environments and operations of bigger and more complex control areas.

2. BACKGROUND

2.1 Ancillary Services Market Process – Stages and Benefits

Figure 1, below, shows an overview of the Ancillary Service Regulation market process as used in the definition of the functional requirements for this reliability adequacy application, with its impact on NERC system reliability compliance parameters such as CPS1, CPS2, DCS and WSCC voltage stability guidelines.

Figure 1 – Ancillary Services Regulation Market Processes – Stages and Benefits



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The process starts, as shown in Figure 1, with ISOs/RTOs preparing their Ancillary Services forecast (Regulation, spinning reserves, etc.) requirements and the supply Bidders using that forecast to present their bids in the Ancillary Services Markets. Any errors in the forecast or discrepancies between actual and bids will impact market efficiencies and system reliability compliance parameters such as NERC CPS1, CPS2, DCS, frequency and WSCC voltage stability margins.

2.2 Ancillary Services Definition and Functional Requirements

2.2.1 Ancillary Services Definition

Ancillary Services, as defined by the Federal Energy Regulatory Commission (FERC) in Order 888, are services that are needed to provide basic transmission service to a customer. These services range from action taken to effect the transaction (such as scheduling and dispatching services) to services that are necessary to maintain the integrity of the transmission system during a transaction (such as load following and reactive power support). Other ancillary Services are needed to correct for the effects associated with undertaking a transaction (such as energy imbalance service).

There are some differences in the terminology used to designate the Ancillary Services by North American Electric Reliability Council's (NERC's) Policy 10 and FERC Ancillary Services, this specification will use the FERC definitions.

Ancillary Services are not new services. Historically, they had been included in the integrated generation and transmission services provided by Control Areas, but under FERC Order 888 these services were required to be unbundled. Over the last decade, electric markets have been significantly restructured throughout the world. Consumers now benefit from a more competitive marketplace and have greater choice in buying electricity and ancillary services. Presently and continuing in the future, the ancillary services are being unbundled and offered separately by operating Authorities, Transmission Providers, as well as third party Ancillary Services Suppliers. Under the old paradigm any difference between demand and supply of Ancillary Services was covered by the vertical integrated utilities. In a competitive market the differences between Ancillary Services supply and demand need to be accounted for and tracked to ensure market efficiency and system reliability.

The Ancillary Services procured competitively, on a daily basis, in the California markets are:

- Regulating Reserves (Regulation),
- Spinning Reserves,
- Non-Spinning Reserves, and
- Replacement Reserves

The first three Ancillary Services correspond to services defined in FERC Order 888. The ISO's fourth Ancillary Service, replacement reserve, is not explicitly defined or required under FERC Order 888, but was included in their tariff to satisfy the Western System Coordinating Council (WSCC) reliability requirements.

2.2.2. Ancillary Services Adequacy Tools Generic Functional Requirements

The four services are collectively referred to as "reserve" Ancillary Services, also the term "Operating Reserves" is commonly used to refer collectively to Spinning and Non-Spinning Reserves. Two other Ancillary Services, voltage supports and black start, are currently procured on a long-term basis by the ISO.

The Four main functions of the ASPTP application are performance, tracking, probabilistic prediction and simulation. In the case of performance monitoring and tracking this application will monitor the supplier's and the system compliance with reliability standards.

- Performance Monitoring and Tracking
  - Suppliers - ASPTP will assist the Operating Authority by monitoring the performance of ancillary service suppliers and comparing their actual performance against their bid(s) (See Figure 4 in Section 4). The performance data for each supplier will be retained and used for tracking and prediction, over a defined period of time, to better represent suppliers overall performance.
  - Host Control Area - ASPTP will monitor and track the Host Control Area's compliance with National or Regional Reliability standards for Frequency, CPS1, CPS2 and DCS.
- Probabilistic predictions - Using the most recent real time data, short term forecast algorithms will provide a short-term probabilistic prediction for the regulation ancillary service. Displays of historic, actual behavior and probabilistic predictions of those variables would be shown to Operating Authority using geographical and graphical visualization technology allowing them to make effective and timing decisions in managing the compliance and reliability of the system.
- Simulation **–** This function will allow training to Operating Authority by running interactive simulations based on historical actual data.

In the prototype the ASPTP application will use Powel's time-series Metered Data Management System (MDMS) as its time series database, and Informational Management System (IMS) as the engine for data collection, validations, comparisons and calculations of the differences between suppliers bids and actual deliverables for regulation, spinning reserve, non spinning reserve and replacement reserve, and for comparisons between the Host Control Area's performance and the NERC and WSCC reliability standards.

ASPTP is being designed to interact with a Host's Energy Management System (EMS) or SCADA and it will reside in a high power PC based workstation, running Windows NT and loaded with the application software, described in this document, specifically designed and implemented for this application.

3. RELIABILITY STANDARDS AND ADEQUACY METRICS

North American utilities formed the North American Electric Reliability Council (NERC) in 1968 to coordinate, promote and communicate about the reliability of their generation and transmission systems. NERC helps utilities work together to maintain or improve system reliability by:

- Developing and maintaining Policies and Standards, for the reliable operation and planning of interconnected electric system in North America.
- Measuring performance of systems for compliance with the reliability Policies and Standards.
- Ensuring compliance with the reliability Policies and Standards through well-defined, effective, and timely procedures.

As of October 1999, NERC has approved nine Policies and Standards, and is defining a tenth policy to deal with the reliability and market aspects of Ancillary Services.

Figure 2 – Standards for a Reliable North American Bulk Electric System

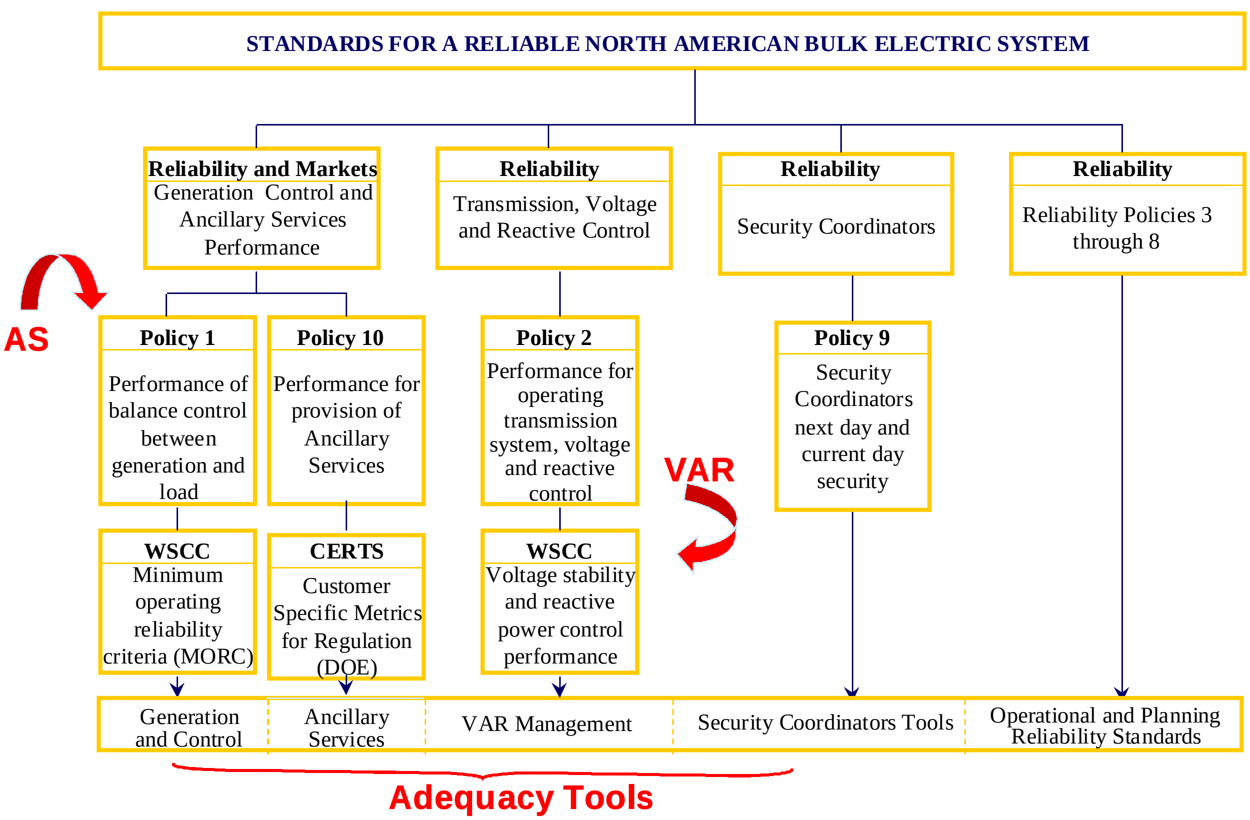

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Figure-2 shows an overview of all ten NERC Policies and Standards with specific details for the functional goals, interrelationships and performance parameters for Policies 1, 2, 9 and 10. CERTS is focused on these four NERC Policies and has identified the need for adequacy operational tools to assist the Operating Authorities to effectively monitor and track performance and anticipate short term future compliance requirements and reliability needs. Performance tools for Policies 1 and 10 and WSCC MORC are addressed with this ASPTP specification and Policies 2 and 10 and WSCC voltage stability guidelines with the VAR Management Specification.

It should be noticed that independent of the deregulation approach and business infrastructures implemented in different areas of the nation, the Operating Authority, such ISOs, RTOs, utilities, etc will be responsible for their control area reliability. Consequently they are in need of real time operational adequacy tools for monitoring system compliance with reliability standards and suppliers compliance with their bids.

3.1 Generation Control and Ancillary Services (NERC Policies 1 and 10) – A Market Perspective

FERC's Order 888 & 889 separated the functions of generation and transmission and stimulated the creation of electricity markets for ancillary services. The competitive market is now providing these ancillary services that were once part of Host Utility's generation services. Those six services called Ancillary Services were defined by FERC (FERC Order 888) and later expanded upon by NERC. All of the Ancillary Services are measurable and can be bid into the marketplace with variation of prices according to offer and demand law.

In the restructured marketplace, by design, generation operators (Suppliers) are free to make their own decisions about how much to generate in any given hour, subject only to the incentives and penalties embodied in market prices and in contractual relationships.

Operating Reserves (Spinning and Non-Spinning Reserves) are mainly called under emergency conditions and must be available within 10 minutes.

California's ancillary services markets have allowed the sellers to determine where their generation would be most valuable, thus enhancing market efficiency. Four primary Ancillary Services, Regulation, Spinning, Non-Spinning and Replacement Reserves are now priced at separated market prices rather than combined in a single uplift charge, or procured together with the commodity energy.

3.2 Generation Control and Ancillary Services (NERC Policies 1 and 10) – A System Reliability Perspective

The Control Area Operator is the person responsible for ensuring system reliability through the compliance of standards established by NERC and WSCC. The WSCC's Minimum Operating Reliability Criteria (MORC) is essential to maintain a reliable operation in the Western Interconnected.

The need for the measurable standards are driven by industry restructuring, namely:

- Industry competition that precludes the reliability councils from relying solely on voluntary compliance and peer pressure to maintain the current level of reliability.
- Divestiture of generation assets resulting in separation of generation resources from traditional reliability bodies, such as Control Areas;
- Separation of generation and transmission functions within previously integrated utilities requiring new protocols to re-integrate the supply and deployment of reliability services; and
- Development of procedures and protocols within emerging regional market structures.

The standards are necessary to ensure these unbundled reliability services continue to be provided under a range of competitive market structures and conditions. These standards also support market goals by providing a uniform set of definitions and rules for Ancillary Services across multiple Control Areas, which makes it easier for Ancillary Services Suppliers and Host system to provide these services.

The Operating Authority must agree and deploy the resources necessary to meet the Control Area generation and demand balancing requirements. However, the resources required include a diverse mix of attributes, since balancing occurs on different time horizons and under both pre- and post-contingency conditions.

Generation and demand balancing requires that a Control Area meet the following criteria as defined in NERC Policy 1 – See Figure 2:

- Control Performance Standard 1 (CPS1). Over a year, the average of the clock-minute averages of a Control Area's ACE divided by -10β (β is the Control Area frequency bias) times the corresponding clock-minute averages of the Interconnection's frequency error shall be less than a specific limit. This limit, ε, is a constant derived from a targeted frequency bound reviewed and set as necessary by the NERC Performance Subcommittee.
- Control Performance Standard 2 (CPS2). The ten-minute average ACE must be within a specific limit (L_{10}) at least 90% of the time within each month.
- Disturbance Control Standard (DCS). For reportable disturbances, the ACE must return either to zero or to its pre-disturbance level within ten minutes following the start of a disturbance.

Each control area shall monitor its control performance on a continuous basis against Standards CPS1 and CPS2. Each control area shall achieve CPS1 compliance of 100% and achieve CPS2 compliance of 90%.

In the simplest form, the resources to meet generation and demand balancing objectives are capacity and the ability to raise and lower output or demand in response to control signals or instructions. Generators, controllable loads, or storage devices may provide this capacity and maneuverability.

After one year of operation of California competitive bid, ancillary service market demonstrated that system reliability could be maintained while relying on open markets for these essential services.

3.3 Ancillary Services Metrics

Table 1 is CERTS proposed overview for the Ancillary Services metrics required to meet the performance, tracking and prediction requirements in a deregulated environment and adhering to evolving reliability standards. Supplier and System ancillary services metrics will be implemented using graphical visual analysis.

Table 1 - Ancillary Services Metrics

Entity / Horizon	SUPPLIER	SYSTEM	
		Security Coordinators (ACE, Frequency)	Control Area (CPS1, CPS2)
Performance (Last 1m-24h)	Generation or Load Response to Control Signals	RMS Value of ACE and Frequency Deviation Readings in one Minute	NERC Policy-1 CPS1 for 1-Minute Window
Tracking (Last 1d-30d)	NERC Policy-10 Performance Criteria	Equivalent to Performance	Equivalent to Performance
Prediction (Next 1h-48h)	Regulation Forecast	Load Forecast Regulation Forecast	

4. ASPTP FUNCTIONAL REQUIREMENTS

Based on stakeholders' experiences with Ancillary Services markets and the requirements they have identified as key to reliable operate power systems, the ASPTP major functional capabilities have been identified and designed to respond to these requirements are:

- Monitor the performance of Ancillary Services suppliers and the Operating Authorities use of them for meeting National/Regional reliability standards.
- Track and archive the performance to feed the historical time series database, which is used to identify past behavior and performance of suppliers and Host.
- Forecast the Ancillary Services requirements allowing Operating Authorities to make prudent and timely decisions in the operation of the system.
- Simulation allowing the Operating Authority to receive training by running interactive simulations.

The above four major ASPTP functional capabilities are applied for each of the Host Ancillary Services that are necessary to ensure system reliability are as follows.

- Regulation: Generation that is already up and running, and synchronized with the HOST controlled grid so that the megawatts generated can be increased (incremented) or decreased (decremented) instantly through automatic generation control (AGC). Regulation is used to maintain real-time balance on the system.
- Spinning Reserves: Generation that is already up and running, or "spinning", with additional capacity that is capable of ramping over a specified range within 10 minutes and running for at least two hours.
- Non-Spinning Reserves: Generation that is available but non running, that is capable of being synchronized and ramping to a specified level within 10 minutes, and then capable of running for at least two hours.
- Replacement Reserves: Generation that is available but non running, that is capable of being synchronized with the HOST controlled grid and ramping to a specified load within one hour, and running for at least two hours.

In addition, ASPTP will follow California market zonal structure for Ancillary Services and congestion management. The HOST system is divided into geographic zones. The zones are defined so that congestion within them is infrequent and has little operational impact, while congestion across zonal interfaces tends to be predictably frequent and to have significant impact.

4.1 ASPTP Integrated Functional Overview – Figure 3

The purpose of the ASPTP application is to provide sufficient and meaningful information for Operating Authorities to:

- Maintain system reliability by helping to comply with control guidelines, and

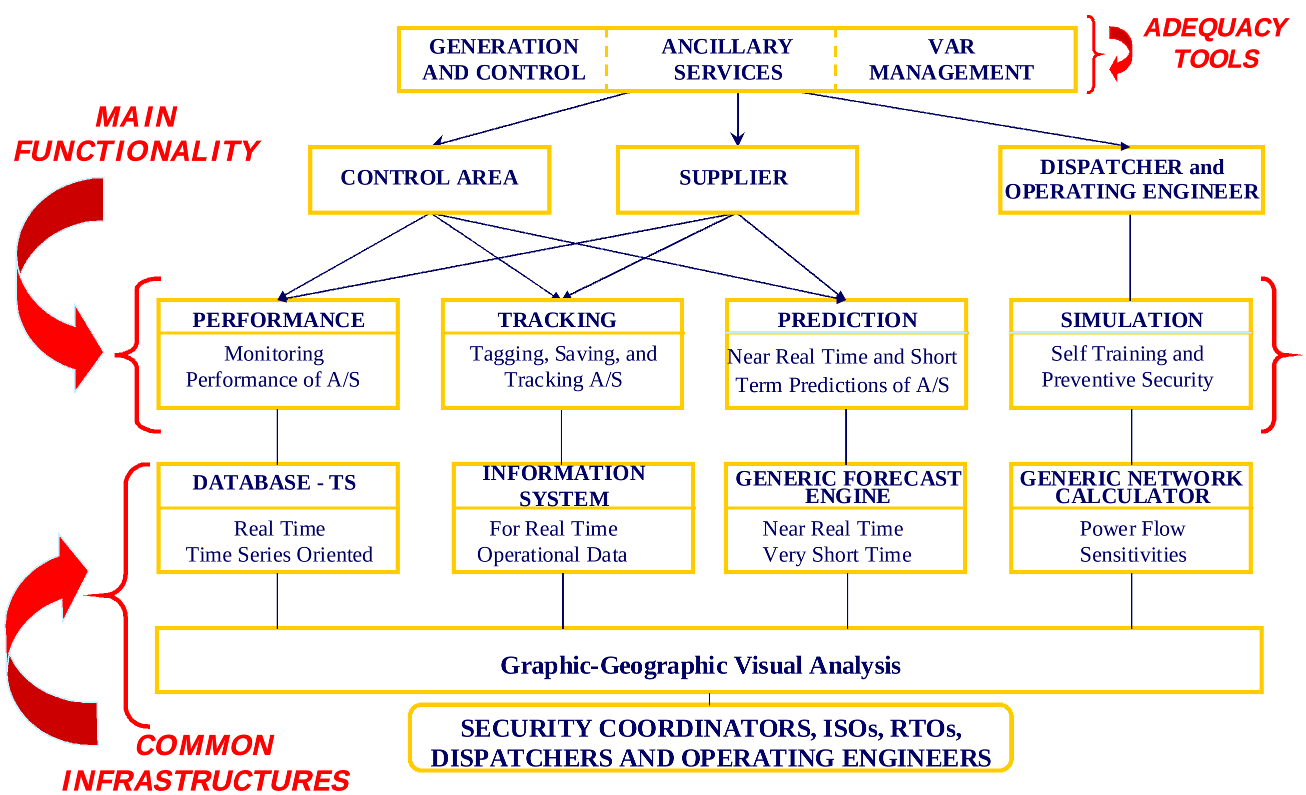
- Improve the efficiency and reliability of the Ancillary Services market

Figure 3 shows a general overview of the ASPTP application functionality. It also illustrates the relationships of each of the Ancillary Services with the ASPTP database, information system, Generic Forecast Engine, visualization layer and the Operating Authority and/or Operation Engineers.

The ASPTP application major functional capabilities are:

- Performance. Monitoring the performance of the Ancillary Services provided by Suppliers to Host, and the Host compliance with their Control Area reliability standards. Actual data is compared with updated scheduled or bid values for regulation, spinning reserves, non-spinning reserves and replacement reserves, in order to evaluate suppliers compliance with their bid. The Host's performance is evaluated in its procurement and deployment of the necessary services to meet reliability standards, as established in NERC Policy 1, Policy 10 and WSCC's MORC.

Figure 3 – ASPTP Integrated Functionality and Relationships with Market and Reliability



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- Tracking. Time tagging and archiving actual deliveries, updated scheduled values and suppliers control error for regulation, spinning reserve, non-spinning reserve and replacement reserve. Data shall be stored in a time series database used to present to the

Operating Authority the pattern and behavior of the ancillary service suppliers, and to feed historical data series for prediction purposes.

- Probabilistic prediction. Provide the Operating Authority with a prediction of up coming regulation, operating reserves (spinning, non-spinning) and replacement reserves requirements. A more accurate forecast of the up coming requirements will allow the opportunity for a more efficient match between the generation requirements and customer's load. In addition, the improved probabilistic prediction accuracy will allow Operating Authorities to maintain and improve system reliability and market efficiencies. It has been identified that competitive markets require forecast horizons different that in the past. Table 2, below, is CERTS overview of the new overall infrastructure required to meet the forecast requirements in a deregulated environment. The shaded areas are being addressed in this specification.

Table 2 – Probabilistic Forecast Needs Within Competitive Electricity Markets

Consortium for Electric Reliability Technology Solutions (CERTS)

Probabilistic Forecast Needs Within Competitive Markets

STAGE	HORIZON	ISOs & RTOs	Power Exchanges	Bidders (Supply & Demand)
Planning	*Yearly*	*LTF*		
Planning	*Monthly & Weekly*	*LTF*		
Day Ahead	*Day Ahead Markets*	*STF*	*STF*	*STF*
Daily	*Day Of Markets*	*VSTF*	*VSTF*	*VSTF*
Real Time Operations	*Hourly Markets*	*NRTF*	*NRTF*	*NRTF*

LTF = Long Term Forecast ***STF = Short Term Forecast*** ***VSTF = Very Short Term Forecast***
NRTF = Near Real Time Forecast

Addressed in this specification

HOST0720

- Simulation. The ASPTP application is designed to allow Dispatchers and Operation Engineers the ability to run interactive simulations for "what if" assessments and/or self-training purposes.

The ASPTP Visual Analysis layer has been designed to facilitate the interpretation of the results from each of the four major functions. Taking advantage of the visualization technology available, it presents past, current and near term future information for Operating Authority on tabular, 2D and 3D graphical, geographic, concurrent and animated visualization displays.

4.2 Ancillary Services Suppliers Performance Definitions

The ASPTP application shall monitor the actual performance of Ancillary Services provided by Suppliers to Host System under normal and/or disturbance conditions to verify Suppliers and Host's resources meet reliability performance criteria. This section specifies the requirements that are applicable for all Ancillary Services.

The measurement method quantifies the energy and variability associated with the Ancillary Services scheduled output, and Supplier Control Error (SCE). If the Ancillary Services Supplier has multiple active schedules, the Ancillary Services scheduled output is the sum of all active schedules. The Supplier Control Error (SCE) is the difference between the Ancillary Services actual output and the Ancillary Services scheduled output. The Ancillary Services Supplier delivery error is completely defined by the SCE. Ancillary Services measurement includes:

1. Quantifying Ancillary Services scheduled output maximum capability and actual utilization, and
2. Quantifying Supplier Control Error energy and variability

All real-energy Ancillary Services are dispatched within a smaller time interval than the block energy scheduling period. The block energy-scheduling period is typically 1 hour. An Ancillary Service Supplier of Regulation may receive a new scheduled output every AGC cycle (typically 4 seconds), and Operating Reserves may be loaded and ramped out completely within a scheduling period. The measurement method needs to quantify the energy and variability associated with Ancillary Services schedules and SCE within each scheduling period.

4.3 Supplier and System Performance Criteria and Performance Calculations

Generic Supplier Control Error (SCE) – Definition. The expectation for any real-energy Ancillary Services Supplier is that the Ancillary Services Resources follow the continually updated variable schedule. By following this schedule, the Ancillary Services Supplier provides the real-energy response that allows the Operating Authority to meet the CPS and DCS reliability performance standards defined in Section 2.2. An Ancillary Services Supplier that has multiple active schedules is expected to follow its total scheduled amount. The Supplier Control Error (SCE) is the error between actual output and all active schedules. The active schedules can include a mix of energy, Regulation, and other real-energy services.

$$\text{Supplier Control Error} = (\text{SCE}) = (P_a - P_s)$$

Where: P_a = Ancillary Services Supplier Actual metered power

P_s = Sum of all schedules at each sampling period for this Ancillary Service Supplier

Table 3, below, shows that there are two sets of criteria to monitor the performance of the Ancillary Services. The first one refers to the Ancillary Services themselves with its performance parameter the Supplier Control Error (SCE). The other one refers to the system and its related performance parameters CPS1, CPS2 and DCS.

Table 3 – Ancillary Services Performance Criteria

Level	Types	Compliance Criteria	Rate
Ancillary Services	Regulation	StDev (SCE) < Sigma	-
	Spinning Reserve	0% ≤ SCE ≤ 10%	Full length of disturbance
	Non-Spinning Reser	0% ≤ SCE ≤ 10%	Full length of disturbance
	Replacement Reser	-	-
System	Frequency	Historical thresholds	Hourly
	CPS1	CPS1 - comp. 100%	1-Min average of 4-Sec resolution
	CPS2	CPS2 - comp. 90%	1-Min average of 4-Sec resolution
	DCS	ACE < 80% of largest contingency or 300 MW	10 min

4.3.1 Supplier Control Error (SCE)

The Supplier Control Error (SCE) is the error between the Ancillary Services actual output and all active schedules.

For **regulation** the criterion requires the long-term standard deviation of the Supplier Control Error to be less than a specific value. The following equation mathematically represents the proposed criterion. This inequality must be met for 90% of the periods in a month in order to achieve acceptable performance.

$$[\mathrm{StDev}\{|SCE_{sampled}|\}_{hour}] \leq \boldsymbol{\sigma}_{\mathbf{limit}}$$

Where: $SCE_{sampled}$ = Supplier Control Error at the sampled rate

For **spinning reserve and non-spinning reserve** the criteria establish that Supplier Control Error shall be greater than 0% and less than +10% of the deployed MW amount during disturbance recovery.

4.3.2 System Performance Parameters CPS1, CPS2 and DCS

For the System the performance criteria establish that a Control Area meet the CPS1, CPS2 and DCS.

Control Performance Standard 1 (CPS1). This parameter measures control impact on frequency and is calculated from a MW-Hz error value computed over a sliding 12-month period. Over a year, the average of the clock-minute averages of a Control Area's ACE divided by -10β (β is the Control Area frequency bias) times the corresponding clock-minute averages of the Interconnection's frequency error shall be less than a specific limit. This limit, ε, is a constant derived from a targeted frequency bound reviewed and set as necessary by NERC Performance Subcommittee. To allow for effective tracking and preventive actions, ASPTP calculates CPS1 for different time windows besides the yearly value requested by NERC.

Area Control Error (ACE). The instantaneous difference between actual and scheduled interchange, taking into account the effects of frequency bias.

Area Control Error (ACE) = (Pa – Ps) - β (Fa-Fs) – 0.3 β (Time Error)s

Pa = Actual interchange, in MW; Ps = Scheduled interchange, in MW

Frequency Bias β. A value, usually given as MW / 0.1 Hz. β = 220 MW / 0.1 Hz for California

CPS1 measures the variability of ACE related to frequency. The frequency-related parameter, CPS1, converts a compliance ratio to a compliance percentage as follows.

$$CPS1 = (2 - CF) * 100\%$$

The frequency-related Compliance Factor, CF, is a ratio of all one-minute compliance parameters accumulated over 12 months divided by the Target Frequency Bound:

$$CF_{period} = [ACE / (-10\beta)]_{period} * \Delta F_{period}$$

For CPS1 to be statistically valid, ACE should be calculated at least fifteen (15) times per minute. These sub-minute calculations are averaged on each clock-minute and compare against a specified value ε_1. The value ε_1 is a constant target one-minute RMS average frequency error over a year and is established by NERC. ε_1 = 22.8 MHz for WSCC

Clock-minute averages of a Control Area's ACE

$$ACE_{clock\text{-}minute} = \frac{\sum ACE_{\text{sampling cycles in clock-minute}}}{n_{\text{sampling cycles in clock-minute}}}$$

ΔF is the clock-minute average of frequency error from schedule, ΔF = Fa – Fs, where Fa is the actual and Fs (60 Hz) is scheduled frequency for Interconnection.

Clock minute average of ΔF

$$\Delta F_{clock\text{-}minute} = \frac{\sum \Delta F_{\text{sampling cycles in clock-minute}}}{}$$

$n_{\text{sampling cycles in clock-minute}}$

The control area's clock-minute compliance Factor (CF) becomes:

$$CF_{\text{clock-minute}} = [ACE / (-10\beta)]_{\text{clock-minute}} * \Delta F_{\text{clock-minute}}$$

The compliance factors are saved in hourly accumulations so that the monthly report will identify the hours in a day in which performance is poor.

Hourly Average. Normally, sixty (60) clock-minute averages of the reporting area's ACE and of the respective Interconnection's frequency error will be used to compute the respective Hourly Average Compliance parameter

$$CF_{\text{clock-hour}} = \frac{\sum CF_{\text{clock-minute}}}{n_{\text{clock-minute samples in hour}}}$$

Accumulated Averages.

$$CF_{\text{clock-hour average-month}} = \frac{\sum_{\text{days-in-month}} [(CF_{\text{clock-hour}})(n_{\text{one-minute samples in clock-hour}})]}{\sum_{\text{days-in-month}} [n_{\text{one-minute samples in clock-hour}}]}$$

$$CF_{\text{month}} = \frac{\sum_{\text{hours-in-day}} [(CF_{\text{clock-hour average-month}})(n_{\text{one-minute samples in clock-hour averages}})]}{\sum_{\text{hours-in-day}} [n_{\text{one-minute samples in clock-hour averages}}]}$$

The 12-month Compliance Factor becomes:

$$CF_{\text{12-month}} = \frac{\sum_{i=1}^{12} [(CF_{\text{month-i}})(n_{\text{(one-minute samples in month)-i}})]}{\sum_{i=1}^{12} [n_{\text{(one-minute samples in month)-i}}]}$$

Equivalent calculations are archive in the ASPTP database for the other CPS1 time windows this application displays to Dispatchers.

Control Performance Standard (CPS2). The average ACE for each of the six-ten minute periods during the hour (i.e., for the ten-minute periods ending at 10, 20, 30, 40, 50 and 60 minutes past the hour) must be within specific limits referred to as L_{10}. Each hour the numbers of violations are counted.

For CAISO L_{10} = 193 (after individual calculations for PG&E, San Diego and SCE companies).

Calculation of Compliance. Each control area shall monitor its control performance on a continuous basis against standards CPS1 and CPS2. Compliance to the two measures is outlined below:

Control Compliance Rating = Pass if CPS1 $\geq$ 100% and CPS2 $\geq$ 90%
Control Compliance Rating = Fail if CPS1 $<$ 100% and CPS2 $<$ 90%

Disturbance Control Standard (DCS). The standard requires that, within ten minutes following a disturbance, Control Area’s ACE must return to zero or to the ACE value that existed immediately prior to the disturbance.

A disturbance must be reported if the magnitude of ACE from the disturbance reaches 80% of the Control Area’s or Reserve Sharing Group’s largest contingency or 300 MW.

Each disturbance is stored in a non-fixed interval time series at the time point when the disturbance starts with a value that is equal to magnitude of the disturbance, and a value that is the number of seconds (or minutes) before the disturbance is cleared. In addition the number of disturbances that is not cleared after 10 minutes within an hour is stored in an hourly time series.

4.4 ASPTP – Probabilistic Forecast Capabilities

The Ancillary Services probabilistic predictions goal is to provide the Host with the most accurate short term forecasts within the time frames shown in Table 2, in section 3.1. There are three stages in the ASPTP prediction process, Near Real Time Forecast (NRTF), Very Short Term Forecast (VSTF) and Short Term/Long Term Forecast (STF/FTF).

- NRTF is the model used for the Host’s regulation, spinning reserves, non-spinning reserves and replacement reserves probabilistic predictions up to 3 hours. The NRTF model uses the most recent one-hour actual data to adapt its model parameters online. The Host NRTF forecast model would be defined and tuned to get the best probabilistic predictions for the Host’s load and reactive reserves. (Only regulation up/down predictions have been implemented in the prototype).
- VSTF is the model used for the Host’s regulation, spinning reserves, non-spinning reserves and replacement reserves probabilistic predictions from 4 hours up to 8 hours. The VSTF model uses the most recent one-hour actual data to adapt its model parameters online. The Host VSTF forecast model would be defined and tuned to get the best probabilistic predictions for the Host’s load and reactive reserves. (Only regulation up/down predictions have been implemented in the prototype).
- Short Term Forecast (STF) and Long Term Forecast (LTF) is the model used for Host’s regulation, spinning reserves, non-spinning reserves and replacement reserves probabilistic predictions from 9 hours up to 24 hours (STF) and for 25 hours to 48 hours 9 (LTF) in advance respectively. STF and LTF model uses most recent one-hour actual data to adapt its model parameters online. (Only regulation up/down predictions have been implemented in the prototype).

The Host STF and LTF forecast models will be defined and tuned to get the best probabilistic predictions for Host's regulation, spinning reserves, non-spinning reserves and replacement reserves. A more accurate forecast of the up coming regulation requirements will allow the opportunity for a more efficient match between the generation requirements and customer's load.

The major functional components for ASPTP Predictor are input and output data systems and forecast models.
Input Data. To assure data quality and improved accuracy, the probabilistic prediction component includes a data filtering process from Powel's MDMS for all the raw actual historical input data received from Host hourly (blocks of 900 records hourly with 4-second data). The filtering process ensures good data points remain unaltered, while gross outliers (out of data range) are replaced by statistically filtered interpolates. The bad data that is detected will be replaced, but it will also be retained in the database.

- Forecast Models Processing.
  Adaptable Models Parameters – To improve the forecast accuracy continuously and dynamically the parameters for the VSTF models are adapted online every time the most recent actual data becomes available, normally hourly.
  Zonal Modeling Capability – The probabilistic prediction component has the capability to subdivide the system into several zones and create models for each zone.
  Automatic Interface with Input / Output – The probabilistic prediction allows the Dispatchers to modify its forecasts interactively. To help them with this interactive capability, it calculates and displays hourly incremental rates such as MW/ºF.
- Output Data – The probabilistic prediction has the following types of outputs:
  User Adjustable (Incremental Rates)- The probabilistic prediction will calculate and display hourly the following four tables of incremental rates: Host regulation change (up or down) as function of time (MW/min) and Host regulation change as function of temperature (MW/ºF). The Operating Authority, using the tables of incremental rates, can modify the probabilistic prediction interactively. If the Operating Authority is using load variation table as a function of the temperature, they can perform some "what if" scenarios: What will the regulation forecast be if the temperature increases by 1º F? The Operating Authority enters the value of the expected temperature increase (1ºF) (in a specific region of the control area) and the predictor will adjust the former load probabilistic prediction and show the revised load profile, that corresponds to the new temperature.
  Probability Results. The Probabilistic Predictor writes its probability results into Powel's ASPTP time-series oriented database. With this information the Operating Authority can know the range of probabilities for each forecast variable.
  Graphical and Tabular Interfaces. Results of forecast models and data mining results are presented to the Operating Authority using effective graphic aids. These types of outputs will allow an easy interpretation of results. Details are described in the output section.

5. ASPTP INPUT AND OUTPUT DATA REQUIREMENTS

5.1 ASPTP Input Data Required

Table 4, below, summarizes the input data required for the ASPTP Application.

Data required from Host to monitor the performance, tracking and predictive the Ancillary Services addressing in this specification is:

Data required from the system is:

- Operating Date/Hour
- Bid Area (NP15 or SP15)
- Requested Set point (MW)
- Frequency, in Hz
- ACE, in MW
- Zonal market clearing regulation-up capacity scheduled, in MW
- Zonal market clearing regulation-up price, in $/MW
- Zonal market clearing regulation-down capacity scheduled, in MW
- Zonal market clearing regulation-down price, in $/MW
- Zonal market clearing spinning reserve capacity scheduled, in MW
- Zonal market clearing spinning reserve price, in $/MW
- Zonal market clearing non-spinning reserve generation capacity scheduled, in MW
- Zonal market clearing non-spinning reserve generation price, in $/MW
- Zonal market clearing non-spinning reserve load capacity scheduled, in MW
- Zonal market clearing non-spinning reserve load price, in $/MW
- Zonal market clearing replacement generation capacity scheduled, in MW
- Zonal market clearing replacement generation capacity price, $/MW
- Zonal market clearing replacement load capacity scheduled, in MW
- Zonal market clearing replacement load price, $/MW
- Gross Power, in MW (1)
- Auxiliary Load Power, in MW (1)
- Net Power Out, in MW (1)
- All Weather Stations Temperatures available, in ºF by Zone
- All Weather Stations Humidity available, in % by Zone

(1) If unit gross and auxiliaries are not monitored, unit output must be NET. It can be compensated, calculated and is required.

Data required from Ancillary Services Suppliers is:

- Operating Date/Hour
- Zonal market clearing regulation-up capacity scheduled, in MW
- Zonal market clearing regulation-down capacity scheduled, in MW
- Zonal market clearing spinning reserve capacity scheduled, in MW
- Zonal market clearing non-spinning reserve generation capacity scheduled, in MW

Table 4 – Real Time Ancillary Services Performance, Tracking and Prediction – Input Data Requirements

REAL TIME ANCILLARY SERVICES PERFORMANCE, TRACKING AND PREDICTION			
Input Data Requirements		**Time Resolution**	
		4-seconds (for 3-months)	**1-hour (for 2-years)**
System Data (1)			
Market Type			
Zone			
Frequency (Hz)		X	
ACE		X	
Forecast Load (MW)			X
Scheduled Load (MW)			X
Actual Load (MW)			X
Edited Actual Load (MW)			X
Temperature (ºF)			X
Regulation Up (MW) - schedule			X
Regulation Up price ($/MW)			X
Regulation Down (MW) - schedule			X
Regulation Down price ($/MW)			X
Spinning reserve (MW) - schedule			X
Spinning reserve price ($/MW)			X
Non-Spinning reserve generation (MW) - schedule			X
Non-Spinning reserve generation price ($/MW)			X
Non-Spinning reserve load (MW) - schedule			X
Non-Spinning reserve load price ($/MW)			X
Replacement generation (MW) - schedule			X
Replacement generation price ($/MW)			X
Replacement load (MW) - schedule			X
Replacement load price ($/MW)			X
Supplier Data (2)			
Regulation Up (MW) - bid			X
Regulation Up (MW) - actual			X
Regulation Down (MW) - bid			X
Regulation Down (MW) - actual			X
Spinning reserve (MW) -bid			X
Spinning reserve (MW) - actual			X
Non-Spinning reserve generation (MW) - bid			X
Non-Spinning reserve generation (MW) - actual			X
Non-Spinning reserve load (MW) - bid			X
Non-Spinning reserve load (MW) - actual			X
Replacement generation (MW) - bid			X
Replacement generation (MW) - actual			X
Replacement load (MW) - bid			X
Replacement load (MW) - actual			X
NOTES:			
(1) All system data should be tagged with date (mmddyy) and time (hhmmss)			
(2) All suppliers data should be tagged with date (mmddyy), time (hhmmss) and generator ID			

- Zonal market clearing replacement generation capacity scheduled, in MW
- Zonal market clearing regulation-up measurement (actual), in MW
- Zonal market clearing regulation-down measurement (actual), in MW
- Zonal market clearing spinning reserve measurement (actual), in MW
- Zonal market clearing non-spinning reserve measurement (actual), in MW
- Zonal market clearing replacement reserve measurement (actual), in MW

Data frequency. Since the point of view of the market**,** the ASPTP application will receive updated data hourly, however, to satisfy operating needs to ensure system reliability, the cycle for readings is 4 seconds, i.e., ASPTP application will read blocks of 900 sets of data (ACE and frequency) hourly. (15 by minute by 60 minutes = 900).

Values received from each supplier are for each operating unit and service type modeled in the MDMS system, i.e., this can either be only one total unit, one for each component, or one for each group of components, all-primary supplier and service type.

5.2 ASPTP Output Data

The output data is:

- Operating Date
- Operating Hour
- Frequency
- RMS of frequency deviations for 10, 20, 40, 60 minutes windows
- RMS of frequency deviations for 2, 8, 16 and 24 hours windows
- Control Performance Standard 1 – CPS1 for 60, 180, 300 and 420 minutes windows
- Control Performance Standard 1 – CPS1 for 1, 3, 6, 9 and 12 hours windows
- Control Performance Standard 2 – CPS2
- Disturbance Control Standard - DCS
- Supplier Control Error (SCE), in MW
- Control Area Net load, in MW
- Actual Regulation up/down, in MW
- Forecast Regulation up/down, in MW

6. HIERARCHICAL VISUAL ASSESSMENT AND ANALYSIS FOR ASPTP

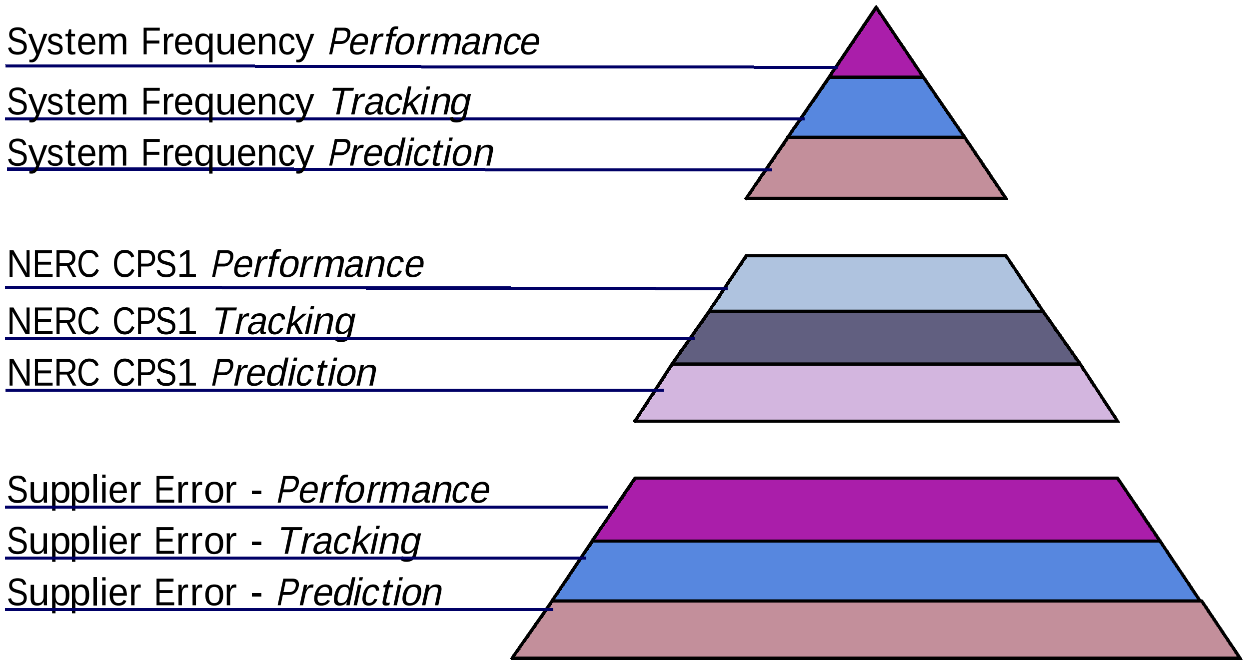
The Ancillary Services components definition described in Table 5 followed a very generic process where the responses to three fundamental questions, what, why and action for the three time horizons were discussed and preliminary agreed, and served to define the visual components and perspectives for this application

Table 5 – Visual Analysis Definition Process

Visual Analysis / Tools Horizon	*WHAT* is Happening	*WHY* is Happening	*ACTION* Corrective Predictive
Performance (Last 1m-24h)	Alarms, 2D/3D parameters pattern	Superposition of cause and effect	Distances from collapse point
Tracking (Last 1d-30d)	Control parameters deviation from reliability standards	Deviation from reliability standards	Probabilistic approach. To be defined
Prediction (Next 1h-48h)	Near real time predictions for key parameters	Causes prediction based on effects predictions	Pattern recognition approach. To be defined
Simulation	10 m to 72 h windows for historical data	10 m to 72 h windows for historical data	10 m to 72 h windows for historical data

The design criteria for the layout of user displays is following an equivalent approach to the one used for SCADA and EMS displays. It has been demonstrated by Dispatchers that the more effective operational displays are those that follow a hierarchical approach to present operational data. In this hierarchical approach, very critical data is presented at the high level on a very simple system display. From the high-level system display Dispatchers go to lower level detail displays levels in the hierarchy. Figure 4 shows the three major categories of displays, System Frequency, CPS1 and Supplier Error, with its corresponding sub-displays for performance, tracking and prediction for the ASPTP application. Most of the displays are 3D or 2D graphic-geographic displays some of them animated.

Figure 4 – Hierarchical Display Levels for ASPTP Visualization



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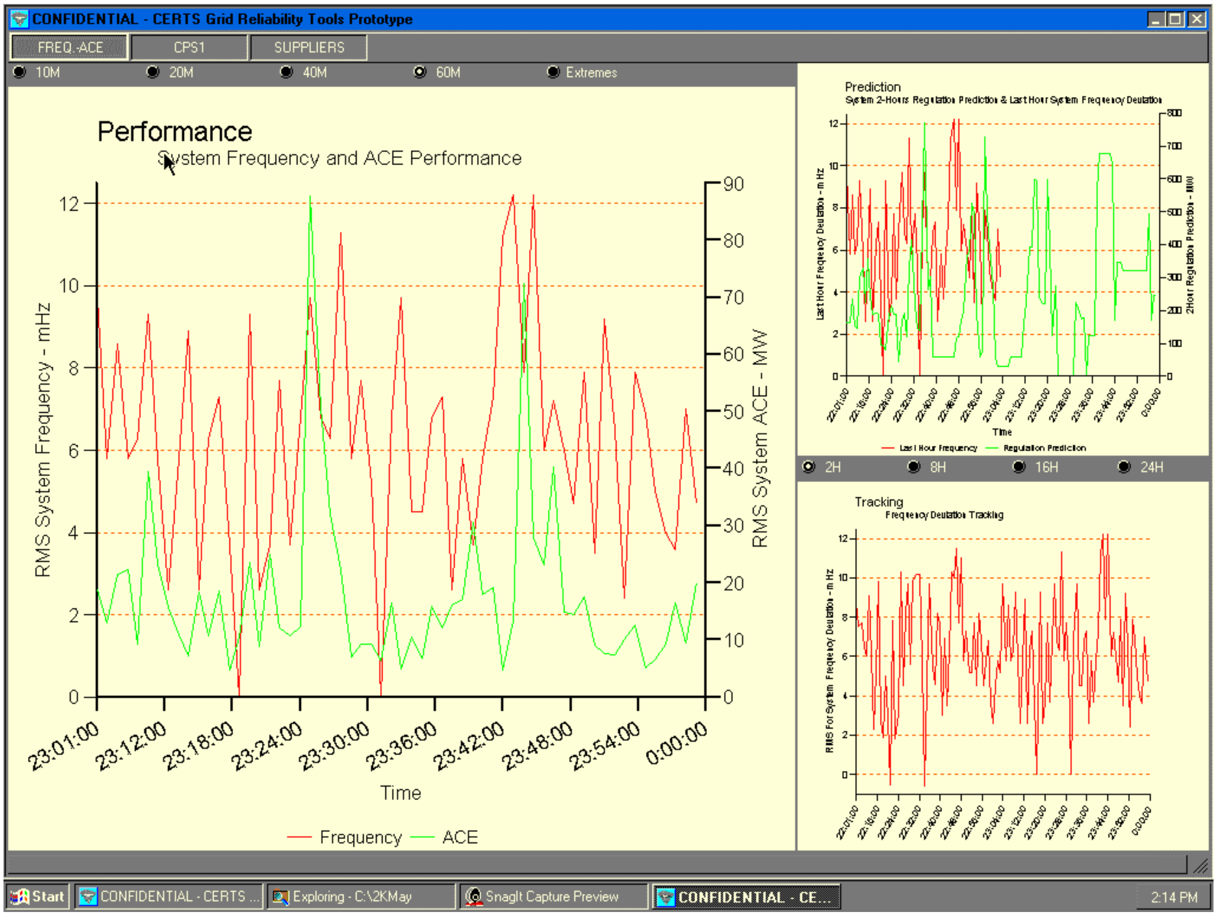
6.1 System Performance, Tracking and Prediction Visual Components

6.1.1 System Frequency and ACE Control Performance, Tracking and Prediction

Figure 5 shows the main frequency / ACE performance visual perspective created with the Visual Analysis Tool with three components on the perspective. The Performance component, on the left side, shows the RMS value of 1-minute averages of frequency deviation (mHz) in the y-axis for four time windows 10, 20, 40 and 60 minutes in the x-axis. The "Extremes" button shows all the RMS values that are above 0.03 mHz. The Tracking component at the bottom-right shows the RMS value of 1-minute averages of frequency deviation for four time-windows 2, 8, 16 and 24 hours frequency performances in mHz. The "Extremes" button shows all the RMS values that are over 0.03 mHz. The Predictive component top-right corresponds to the regulation forecast for the next 2 hours together with the RMS value 1-minute averages of the last 2 hours.

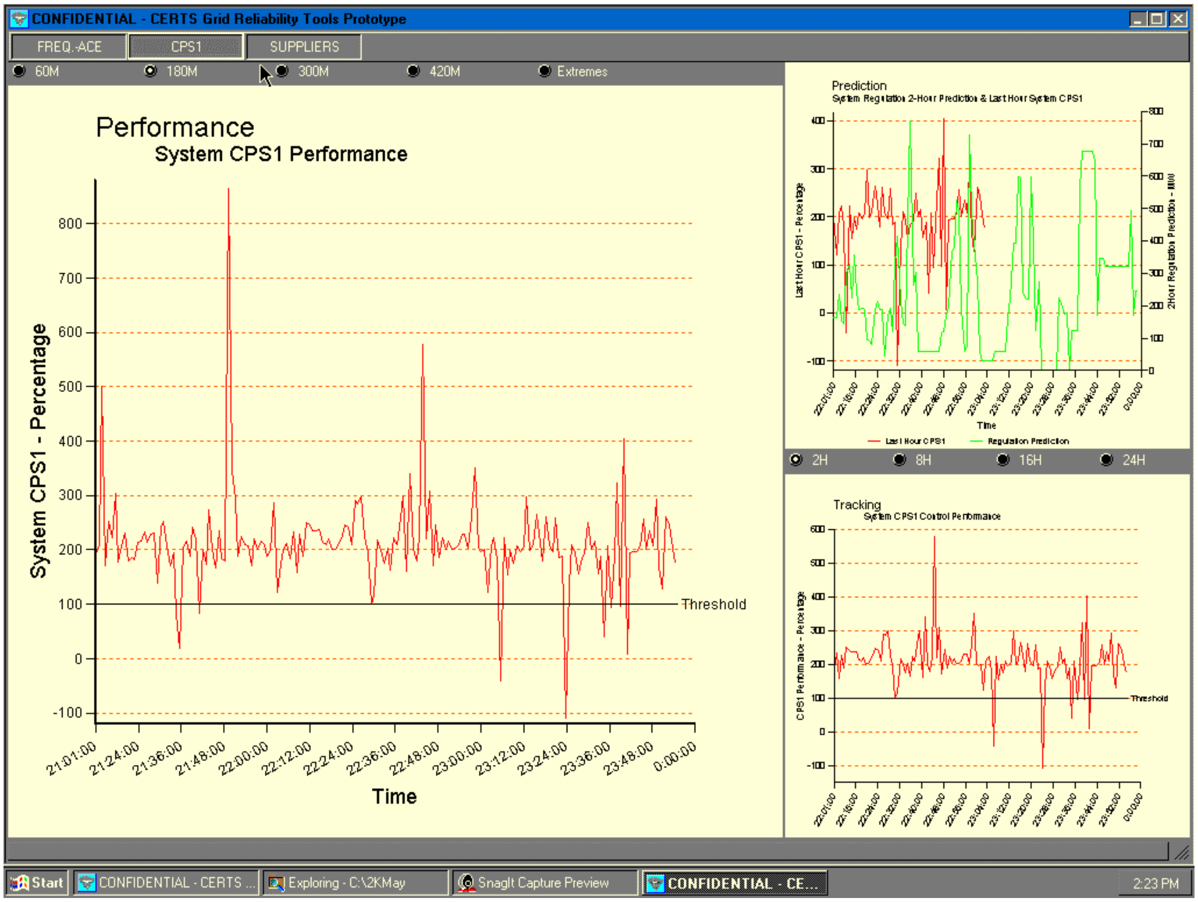
Figure 5 – System Frequency / ACE Control Performance, Tracking and Prediction



6.1.2 System Control Performance Standard CPS1 Performance, Tracking and Prediction

Figure 6 shows the main CPS1 visual perspective created with the Visual Analysis Layer with three visual components on the perspective. The Performance component on the left side shows the CPS1 percent performance (compliance) in the y-axis for four time windows 10, 20, 40 and 60 minutes in the x-axis. The "Extremes" button shows percentages of compliance below 100-percent. The Tracking component at bottom-right similarly shows the CPS1 compliance percentage for 2, 8, 16 and 24 hours. The Predictive component top-right corresponds to the regulation forecast for the next 24 hours together with the CPS1 compliance percentage for the last 24 hours.

Figure 6 – System Control Performance Standard CPS1 Performance, Tracking and Prediction



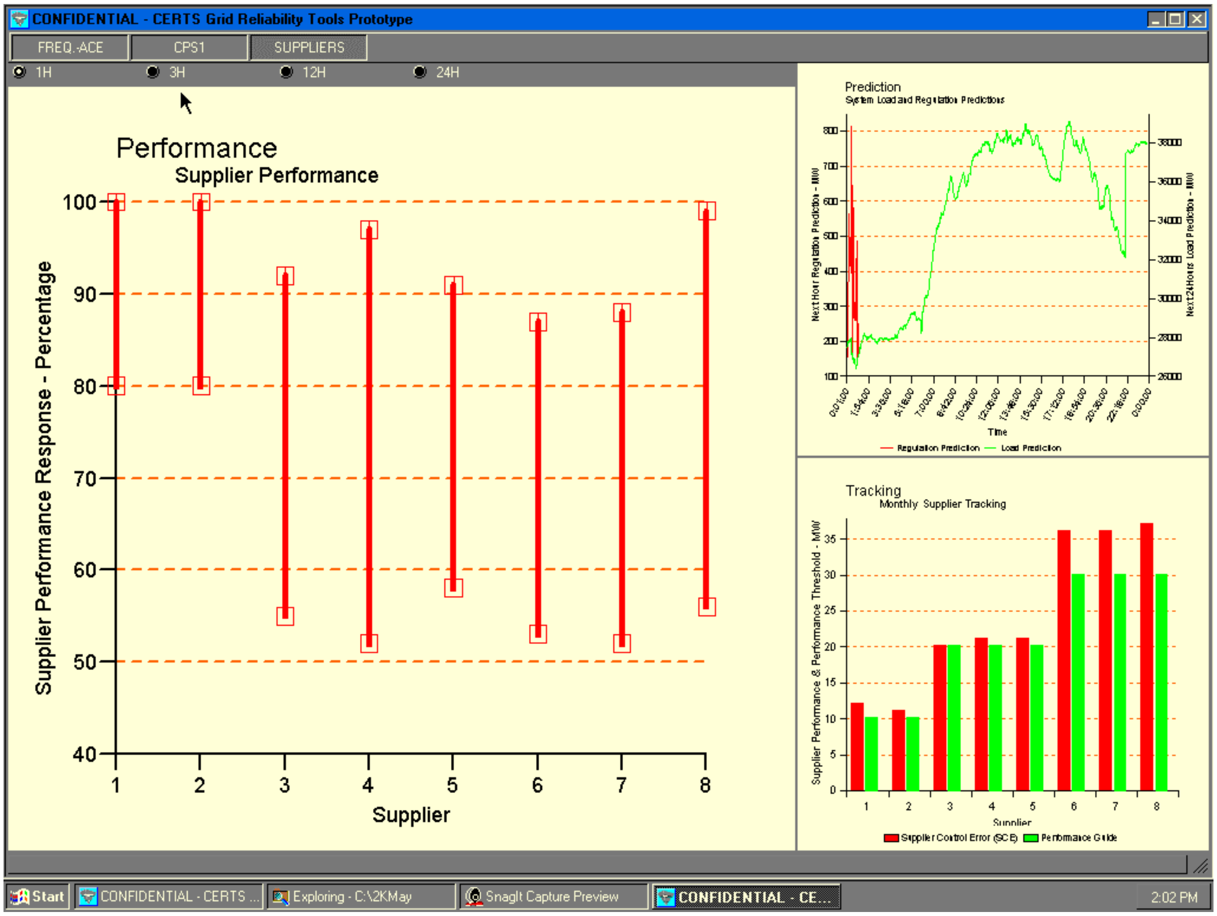
6.2 Supplier Performance, Tracking and Prediction Visual Components

Figure 7 shows the main visual perspective created with the Visual Analysis Layer with three visual components on the perspective. The Performance component on the left side shows the supplier-error in the y-axis for four time windows in the x-axis 1, 3, 12 and 24 hours. On the graph, each Supplier is identified with a number. The buttons on the top let the user to display the graph for the supplier-error performance for the last 1, 3, 12 and 24 hours.

The Tracking component at bottom-right shows the deviation of supplier-error's standard deviation from a preset monthly standard deviation threshold. The upper limit reflects the maximum deviation, according to the criterion establish for the Supplier Error.

The Predictive component top-right corresponds to the load and the regulation forecast for the next 24 hours.

Figure 7 – Supplier Error Performance, Tracking and Prediction

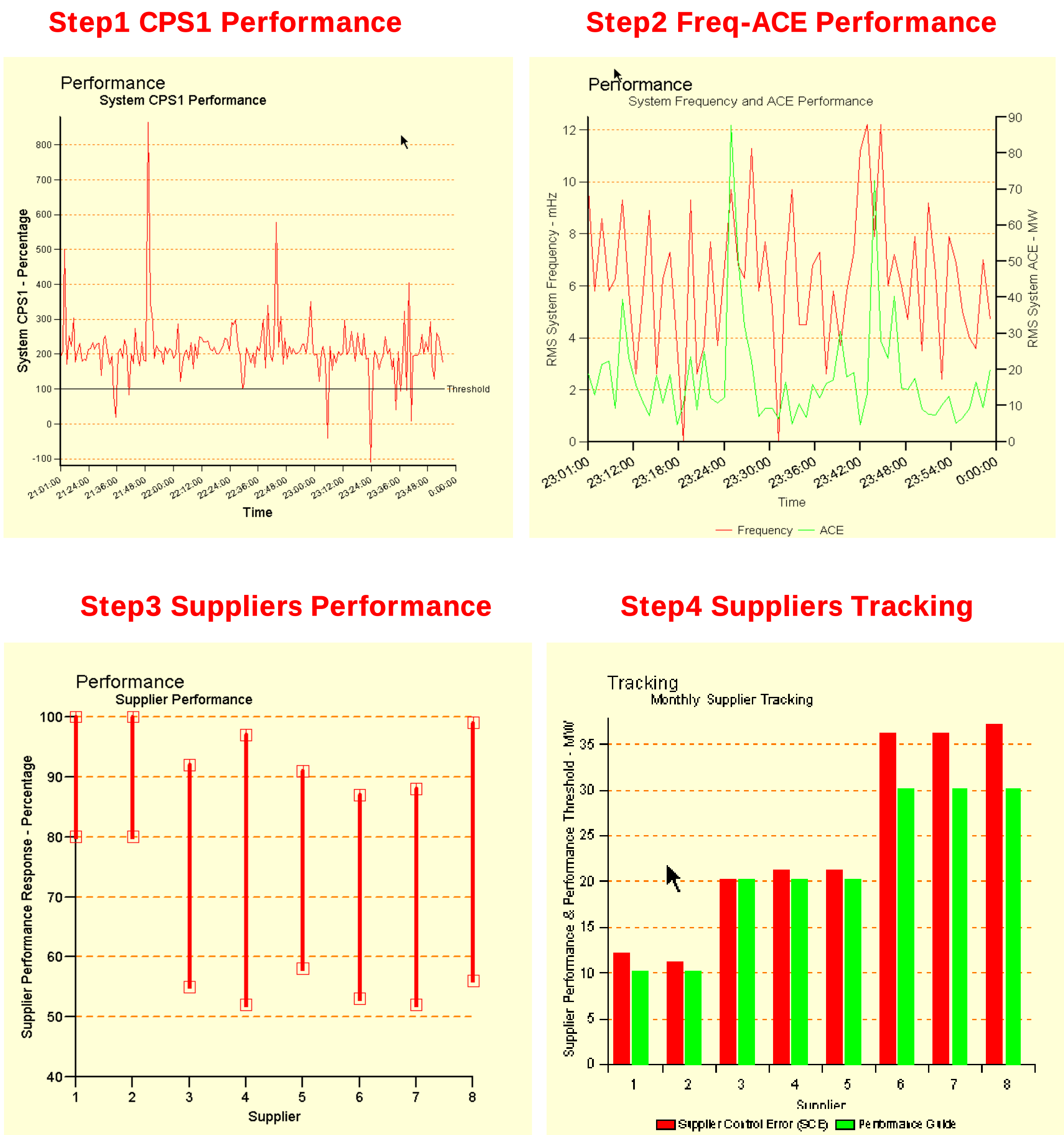


6.3 Control Visual Monitoring, Assessment and Analysis Process

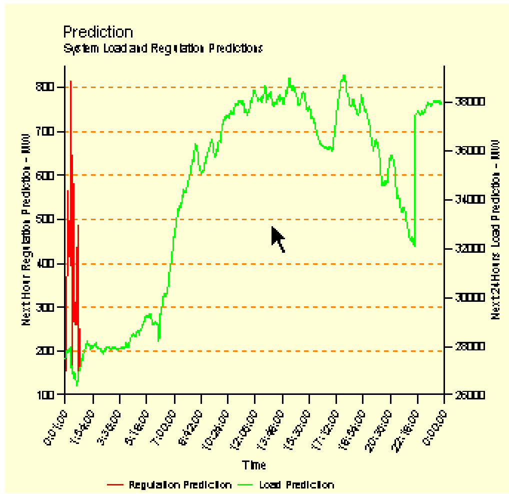
An effective Visual assessment for Control Area performance analysis could involve the following five sequential steps as described in Figure 8.

- Step 1 – CPS1 Performance – Observe Area's CPS1 performance for 10 – 60 minute windows.
- Step 2 – Frequency / ACE – Correlate the ACE / Frequency behavior with CPS1 performance for 10 – 60 minute windows.
- Step 3 – Correlate ACE performance with generation response performance for the same time-windows.
- Step 4 – Suppliers tracking – Observe generation compliance with NERC Policy-10 monthly performance standards.
- Step 5 – Load / Regulation Prediction – Based on the information gathered from steps 1 through step 4, How effectively the Control Area could respond to the forecast Regulation for the next 2-hours and forecast load for the next 24-hours.

Figure 8 - Control Visual Monitoring, Assessment and Analysis Process



Step5 Load-Regulation



6.4 Preliminary Probabilistic Prediction User Interface Capabilities

The Predictor writes its forecast results into Powel's ASPTP time-series oriented database. The visualization modules take the results from the database and display them in graphic or tabular displays predefined by users. The Predictor's user interface displays will be designed to be geographic oriented, user friendly and intuitive. The displays will show information in a logical and consistent manner, and appropriately guide the Dispatchers through the interpretation of results. (Geographical displays have not been implemented in the prototype).

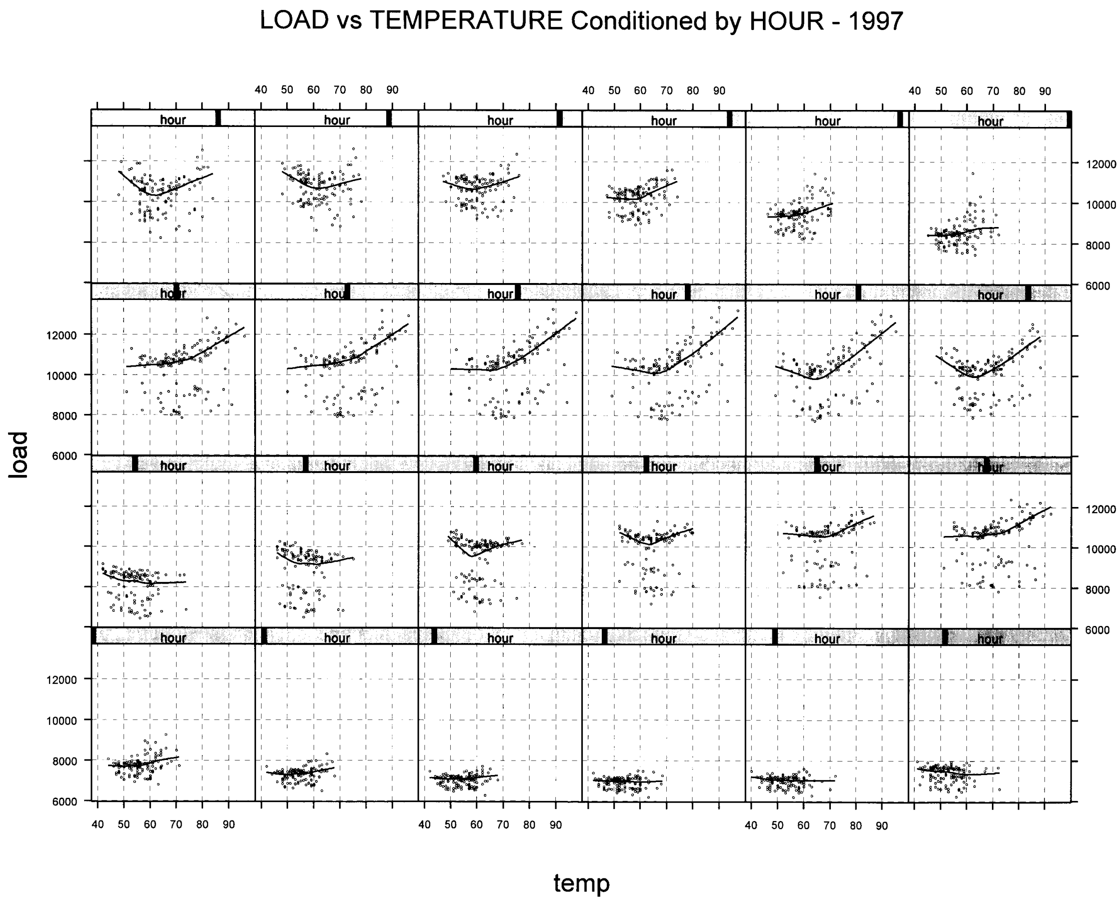
Following are brief descriptions of one sample predictor display. However, the final format of all displays will be agreed with Host users.

6.4.1 ASPTP component – Data Mining with Trellis-graphs Visualization Sample for Load – Clusters Displays

ASPTP time-series oriented database has data mining capabilities for extracting valid, previously unknown, comprehensible data relationships and patterns that are not obvious to operation dispatchers and engineers. Clusters identification is one of these capabilities aim at finding similar parameters sharing a number of useful properties.

Figure 9, is just an example showing visually (Conditioned-graph) the correlation (sensitivity) of load for a range of temperatures for each hour of the day. The graph has been created using historical data for a California power system region for each hour during the year 1997. Equivalent graphs can be created for any three or four parameters and any time period such as holidays, weeks, months, etc.

Figure 9 – Load–Temperature–Hour Relationships – Cluster Display



For each hour, the graph shows the historical load sensitivities for a range of temperature values. Note the left side of the inflection points for most of the hours of the day where load decreases even if temperature increases.

Using data mining with conditioned type graphs visualization, Dispatchers and other users can improve their ability to forecast load. If they know the expected value of temperature for each hour, they can see on the graph the load sensitivity for a given variation of the temperature for any hour of the day. Having this capability will allow the user to improve their decisions in allocating resources efficiently and reliably.

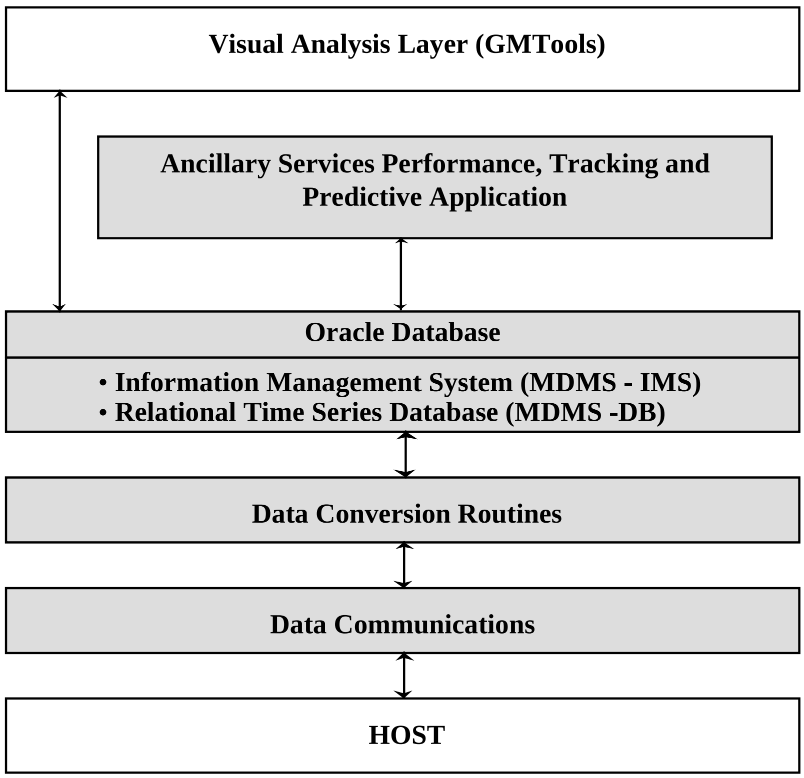
7. DESIGN SPECIFICATIONS

Ancillary Services application design specification has to be oriented to comply with the four functions of the application: performance, tracking, prediction and simulation.

7.1 ASPTP Overview – Figure 10

Figure 10 is an integrated high level view of the ASPTP design and its basic data processing components or layers.

Figure 10 – ASPTP Integrated Functional Infrastructure



Following are functional overviews for each of the infrastructure layers:

- Visual Analysis Technology. To facilitate the interpretation of the models results, a geographic, concurrent and animated user visualization technology is available to present data to the Operating Authority. The visual analysis layer has been designed with a generic integrated but modular approach. This characteristic of the tool not only allows it to extend its use for the Ancillary Services Performance, VAR Management and other prototype applications, but also to take advantage of the most recent predictive algorithm and visualization technology available to present and display flexible accurate probabilistic prediction results to users.

- Ancillary Services Performance, Tracking and Prediction. This is the engine for data collection, comparisons and calculations of the data differences between bids and actual deliverables for regulation, spinning reserves, non-spinning reserves and replacement reserves.
- Information Management System. Based on an Oracle Database, ASPTP includes a real time Information Management System with Data Mining Capabilities to facilitate the Engine's sift to its archive historical data to identify trends, patterns, and correlation among different variables archived. This new information will help System's Operators to effectively interact with ASPTP to improve overall forecast accuracy.
- Time-Series Oriented Database. The Database to support the ASPTP has a specialized, interactive real time and time-series structure. Every element saved in this database is tagged with date and time to improve applications and users accessibility.
- Data Conversion Routines. These are the system's routines to convert the data from the Host format to the MDMS application format.
- Data Communications System. It is the Engine's data communication layer. It will be tailored to meet reasonable HOST input/output data interface requirements.

7.2 ASPTP Integrated Modular Design – Figure 11

Figure 11, is a view of CERTS Grid Management Tools (GMTools), an integrated, modular open architecture structure being used for developing and prototyping CERTS Adequacy applications.

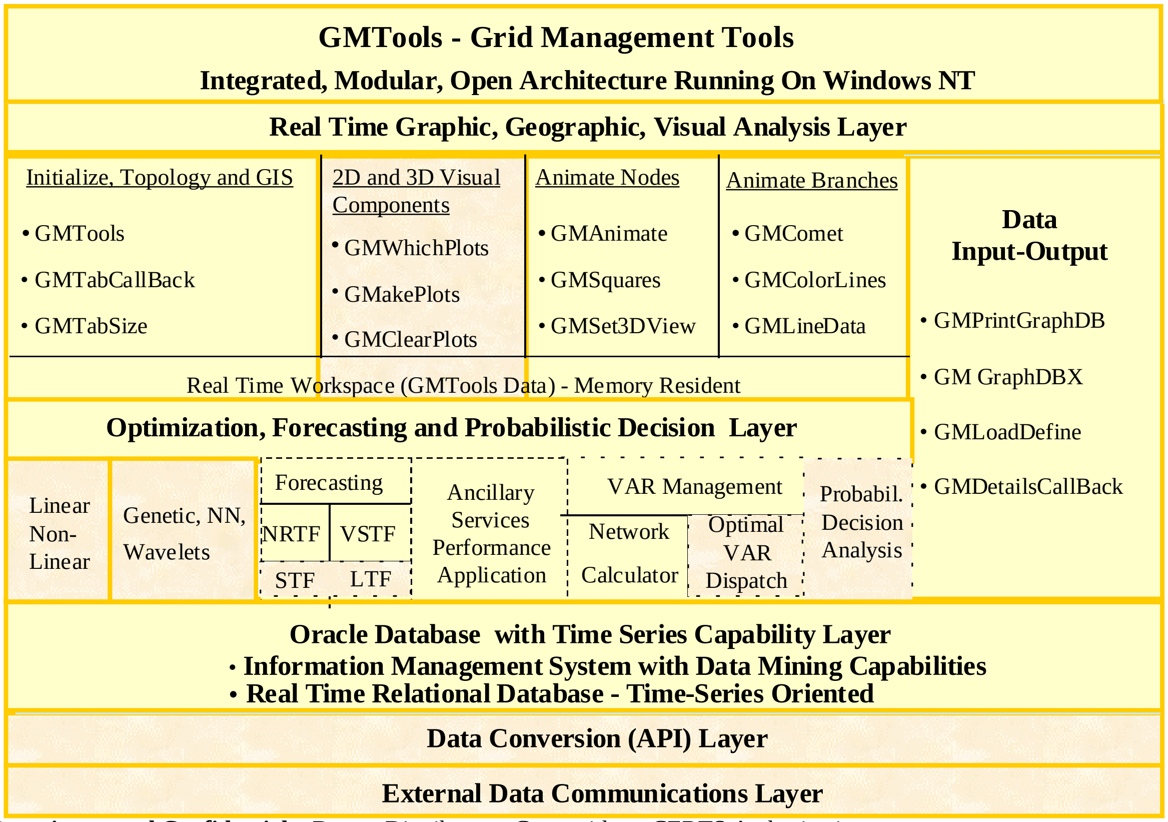
While Figure 10 is a high level overview of ASPTP, Figure 11 shows the integrated modular design components of ASPTP and its predictor with details for the routines currently available in the GMTools visualization layer.

GMTools is being specifically designed and implemented to develop end user reliability applications, training aids and visual analysis technology solutions. These tools will assist in the development of systems that comply with the monitoring, operational and marketing requirements originated by the deregulation and energy markets currently underway worldwide.

ASPTP will utilize GMTools as its primary infrastructure for: data communications, data format conversions, real time time-series oriented database, data mining and the generic forecasting and probabilistic routines. The VAR Management prototype will also use the same GMTools infrastructure.

ASPTP uses the GMTools visual analysis layer to create the hierarchical performance, tracking and prediction displays. Figure 11 is a high level view of this tool. Visualization routines are shown in the upper part (dark line) grouped in five classified blocks according to their utilization. The Visualization Toolbox Layer is a subset of routines, which interface with output data from the optimization, forecasting, probabilistic and decision analysis solvers to present past, current and near term future information for Operating Authority, Operators and Marketers on tabular, 2D and 3D graphical, geographic, concurrent and animated visualization displays.

Figure 11 – ASPTP as an Integrated Component of Grid Management tools (GMTools)



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7.3 ASPTP Performance Function Design.

The ASPTP performance function runs automatically collecting, calculating and archiving the data required for the visualization displays. Some of the variables are:

System Frequency. The ASPTP calculates the RMS value of 1-minute averages of 10, 20, 40 and 60 minutes frequency performance.

Control Performance Standard 1 (CPS1): The compliance factor (CF) to calculate the CPS1 performance criterion, relating ACE and frequency, is calculated every 1-minute interval. This value is used to calculate and store CPS1 every 10 minutes. Then calculations of CPS1 for 1 to 24 hours, 1 day, 1 month or 1 year are done using the CF for the corresponding time frames.

Control Performance Standard 2 (CPS2): At the same time as calculating the CPS1 value, also the performance criterion regarding the need ACE cross zero, within a 10-minute window, within any 40-minute intervals is calculated. This value is calculated hourly. If the criterion is not met a value (1) is stored for this 1-hour interval; otherwise no value is stored.

Disturbance Control Standard (DCS): This criterion is calculated every 4 seconds. If the magnitude of ACE reaches 300 MW or 80% of the Control Area's or Reserve Sharing Group's largest contingency for the given 4-second interval, the percentage error is stored for this 4-second interval, otherwise no value is stored. The DCS time-series has not a fixed interval.

Supplier Control Error (SCE): The SCE is calculated as described in Section 4.3 for each supplier and is stored as a time series with 1-hour resolution. This gives the possibility to directly access this information from other applications without the need to calculate the values. To follow-up the supplier performance, the application calculates, by supplier, the average of the SCE for 3, 12 and 24 hours.

More performance criteria can be added in the future. The design of the function is done in such a way that new criteria can be easily added in the future. The performance of existing criteria can also be changed/altered through different parameters and information structures in the database.

7.4 ASPTP Tracking Function Design

The ASPTP tracking function is run automatically at the start of each hour calculating the results for the last hour.

The tracking calculation is based on the information received from the Host about the amount scheduled for each Ancillary Service and the measured values from each supplier received as 1-hour interval values.

The calculation uses the structural information described in Section 7.1 about how the different supplier services are connected to the different network areas, i.e., which measurements shall be summarized into the resulting total to be checked against the scheduled value.

The difference between the measured total and the scheduled value (SCE) is stored as a time series with 1-hour interval for each network area, Ancillary Service and supplier.

7.5 ASPTP Probabilistic Prediction Function Design

7.5.1 Forecast Models Definition, Calibration and Expected Accuracy

Models. The predictor uses statistical models to forecast Host regulation, spinning, non-spinning and replacement reserves; however, to improve forecast accuracy it is convenient to explore different models for each time horizon. The probabilistic prediction component will have a different model for each variable, regulation, spinning, non-spinning and replacement reserves, and every time horizon (NRTF, VSTF and STF/LTF) tuned to get the best accuracy for each model.

The Generic Forecast Engine is a statistical model and it will be used to forecast the load from 1 hour to 8 hours in advance (NRTF and VSTF). It has been designed with a generic integrated approach for different timeframes and with an information and visualization layer. Furthermore, to improve the forecast accuracy the GFE allows using the most recent actual-historical data available to adapt, to most recent conditions, the forecast model parameters.

The STF/LTF will be done using two different model components that are coupled. The first component (NormLoad) describes the normal load and weather conditions by means of a stochastic state-space model. The time constants for this model are typically 5-15 weeks. This is a stochastic model and Kalman filter technique is used for state estimation.

The second component (DevLoad) describes the deviations in the load from normal conditions. The deviations in the weather variables from normal conditions are the explanatory variables. This model is also modeled by state space formulation. The time constants for this model are shorter than for the “NormLoad” and explain all the deviations in the load, which are not modeled with this model. The parameters of the “DevLoad” are unknown. A recursive prediction error (RPE) method is used to calculate the parameters.

In reference to the LTF, in addition to the forecasting results, the model updating based on actual historical values will produce different interesting results. These are:

- State estimates of load and weather variables
- Model error (Mean Average Percentage Error, MAPE)
- Actual load
- Forecast load with perfect weather
- Forecast error with perfect weather (MAPE)
- Deviation in load caused of the explanatory variables
- Special events
- Temperature corrected load

The model errors indicate the deviation between the actual dependency between load and temperature, and the dependency described in the model parameters. The MAPE is the mean or average of the percentage errors of all the projected data in a forecasting model versus the actual data. See example of MAPE calculation at the end of this section.

The forecast error with perfect weather explains the accuracy of the forecast given a perfect temperature forecast.

The forecast load with perfect weather is a result of a forecast step by step with updating the model for each step. Then the model is shape and ready for the next forecast step.
The simulated load forecast is an ordinary forecast that use the historical measured temperature, and gives to the user a picture of the accuracy of the model given a perfect

temperature forecast.

Special events refers to holidays or special dates like for example “Thanks Giving” or “Christmas period” that affect the normal functioning of big factories and change the normal behavior of the load. All this information has to be given manually to the model.

The forecast region can be divided into several zones. Each zone has it owns forecasting model and actual historical data. It is possible to make a sum of all the zones forecasting results to one forecasting result for the whole region. Within each zone, it is possible to use 5 different measurement points for the explanatory variables, which will give a weighted time series for each variable. The weighting factors are calculated using the relative load to the area where the measurement point is allocated.

The STF/LTF engine can be run in automatic mode. This is very important when there are multiple forecasting zones. The quality assurance historical actual data is input for the updating process, where the model is shaped for the best forecasting performance. The updating process is executed in an automatic mode and the updated model parameters are stored for use in the forecasting process, which is executed when the updating process is finished. Then the forecasting results are stored in the MDMS, ready for the graphical, geographical or tabular presentation layer

Calibration. The Calibration Process is the initial phase during which models are identified and defined and its corresponding parameters defined and tuned to obtain the best accuracy. This process will be done for the types of Host forecast models described in this specification: NRTF, VSTF and STF/LTF and for the four predictors regulation, spinning, non-spinning and replacement reserves. The models require the most recent series of data to be tuned in order to comply with the desired accuracy. To calibrate the tool with the three models, it will be necessary to have the data requested in section 3.5.

Accuracy. The expected predictor accuracy results will be identified once Host actual historical data becomes available.

Table 6 shows the target-forecast accuracy and the probabilistic results obtained by CERTS (NRTF and VSTF) during a test process. ASPTP Predictor will use equivalent algorithms and process for its short term and long term Ancillary Services forecasts.

Table 6 shows four different levels of accuracy expected (for on peak and off peak hours) for each time horizon (1, 8, 24 or 48 hours ahead) for load probabilistic predictions. For example, for 1-hour ahead, the adaptive model predicts the on peak load (MW) with less than 3 % error, 78% of the time.

Table 6 – Accuracy Results for Forecasted Load

PROBABILISTIC FORECAST - TARGET FORECAST ACCURACIES								
Type of Model	***Less Than 0.5%***		***Less Than 1%***		***Less Than 2%***		***Less Than 3%***	
	On-Peak	***Off-Peak***	***On-Peak***	***Off-Peak***	***On-Peak***	***Off-Peak***	***On-Peak***	***Off-Peak***
NRTF Model CAISO - 1 Hr Ahead	**62%**	**52%**	**75%**	**69%**	**91%**	**88%**	**95%**	**95%**
CERTS - 1 Hr Ahead	**18%**	**11%**	**48%**	**26%**	**77%**	**60%**	**96%**	**78%**
VSTF Model CAISO 8 Hours Ahead	-	-	-	-	-	-	-	-
CERTS - 8 Hours Ahead	**10%**	**6%**	**19%**	**15%**	**35%**	**35%**	**52%**	**51%**
STF Model CAISO 24 Hours Ahead	**12%**	**13%**	**27%**	**32%**	**48%**	**59%**	**61%**	**74%**
CERTS 24 Hrs Ahead	**14%**	**16%**	**28%**	**31%**	**49%**	**53%**	**64%**	**68%**
LTF Model CAISO 48 Hours Ahead	-	-	-	-	-	-	-	-
CERTS 48 Hrs Ahead	**14%**	**16%**	**28%**	**31%**	**49%**	**53%**	**64%**	**68%**

NOTES:

1 - CAISO targets were obtained from Sept. 1999 forecast results

1 - CERTS targets were obtained from Sept. 1999 forecast results

Following is an example of MAPE calculations.

COMPUTATIONS OF THE RELATIVE MEASURES FOR A SET OF ERRORS

Period I	Observation Xi	Forecast Fi	Error Xi - Fi	PE (Xi - Fi) *100 / Xi	APE | Xi - Fi |*100 / | Xi |
1	22	24	-2	-9.09	9.09
2	23	28	-5	-21.74	21.74
3	39	32	7	17.95	17.95
4	37	36	1	2.70	2.70
5	38	40	-2	-5.26	5.26
6	47	44	3	6.38	6.38
7	43	48	-5	-11.63	11.63
8	49	52	-3	-6.12	6.12
9	61	56	5	8.20	8.20
10	63	60	3	4.76	4.76
Sums			2	-13.85	93.84

Where APE = absolute percentage error

$$\text{MPE} = \frac{-13.85}{10} = -1.385\%$$

$$\text{MAPE} = \frac{93.84}{10} = 9.384\%$$

7.5.2 Filtering Process for Input Data.

This is the process of verifying the data and looking for outliers before the probabilistic prediction process. If invalid data is found it will be replaced with statistically interpolate values. In addition, input data used by NRTF/VSTF/STF/LTF are classified into two basic categories, one for weekdays and the other one for holidays. These two basic categories of data will allow the models improve forecast accuracy for each category

This process has to be fully automatic, and will follow the steps listed below:

- Read the current raw data from the database
- Run a routine to check if data is missing or not.
- Verify if data is greater than zero and it is not an outlier.
- Replace missing data or outliers with smooth interpolate value.
- The smooth interpolated value will be calculated using statistical routine and the most recent values for the data.
- The new value will be saved into the database, as well as the replaced number.
- Filter data will be used to forecast regulation, spinning reserves, non-spinning reserves and replacement reserves.

7.6 ASPTP Hardware and System Software Requirements

7.6.1 Desktop Workstation

Following are the main hardware and software components for the ASPTP desktop workstation.

- Computer Hardware – PC based, Network Ready Workstation. This platform used by ASPTP will allow users an easy interaction with the Engine. The main characteristics of the workstation will be:
  . Pentium processor – 600 MHz
  . Dual Head CPU
  . RAM Memory – 512 MB
  . Hard Disk capacity – 18 GB
  . Memory Cache – 512 KB
  . Graph card – 8 MB
  . Screen – 20 inches, very high resolution
- Operating Systems – Windows NT or 98. The visualization software tools are taking advantage of several features available in Windows NT or 98.
- Database – Relational Time Series Database with Data Mining Capabilities. These characteristics of the database will allow quick data accessibility and identification of trends and correlations.
- Application Systems – Application Component Languages (Matlab, S-Plus, AVSExpress, GMTools (visualization software)).
- Integration and Database Interfaces – Visual Basic Interfaces used by the predictor of the ASPTP are developed using Visual Basic.

7.6.2 Notebook Workstation

Following are the main hardware and software components for the ASPTP notebook workstation.

- Computer Hardware – Notebook Workstation. The main characteristics of the workstation will be:
  . Pentium processor – 300 MHz
  . RAM Memory – 64 MB
  . Hard Disk capacity – 4.3 GB
  . Memory Cache – 128 KB
  . Graph card – 4 MB
  . Screen – Liquid Crystal Display (LCD) high resolution
- Operating Systems – Windows NT. The visualization software tools are taking advantage of several features available in Windows NT.
- Database – Relational Time Series Database with Data Mining Capabilities. These characteristics of the database will allow quick data accessibility and identification of trends and correlations.
- Application Systems – Application Component Languages (Matlab, S-Plus, AVSExpress, GMTools (visualization software)).
- Integration and Database Interfaces – Visual Basic Interfaces used by the predictor of the ASPTP are developed using Visual Basic.

7.7 Performance Parameters

Data Protocols. There will be two different data protocols used in this application; one will be the data interface protocol between the Host and the ASPTP Application. This protocol could be ICCP, FTP file, Host tailored or TCP/IP. The second interface will be between the ASPTP with its power flow and the visualization layer. This interface will use X-Active protocol.

End User Displays Response Time. There will be two types of display response times, one for data already residing in the MDMS database, and the other one for current data requiring validation or basic calculations:

- The elapsed time between an end user calling a display and the time validated or calculated data already residing on the MDMS database appears on the user display will be less than 15-seconds.
- The elapsed time between an end user calling a display and the time current raw data from the Host System (SCADA / EMS), to which validation and basic calculation are applied, appears on the display will be less than 1-minute, for up to a maximum of 2550 time series.

Data Transfer rates and time limit data storage. The data transfer rates, as well as the time limit data storage for each type of data (time series and state parameters in Metered Data

Management System, MDMS), are specified in Table 4, in section 5 under the time resolution specification, and they could be 4 seconds (for 3 months), or Hourly (for 2-years).

Number of time series for working prototype. The following table shows, as a reference, the number of variables, observations per point and the total time series for workable prototype. Nevertheless, the contractual commitment is for 2550 time series.

Workstation	Variables	Observations per point	Total
Load forecasting			
Weather stations	25	5	125
Load points	25	1	25
Ancillary Services Performance, Tracking and Predictive Application (ASPTP)			
Regulation	150	4	600
Spinning Reserve	150	4	600
Non-Spinning Reserve	150	4	600
Replacement Reserve	150	4	600
Total			2550

Forecast Accuracies. Target accuracies will be the same as shown in Table 6 in the Forecast Specification.

7.8 Future ASPTP Integration within HOST Systems, Figure 12

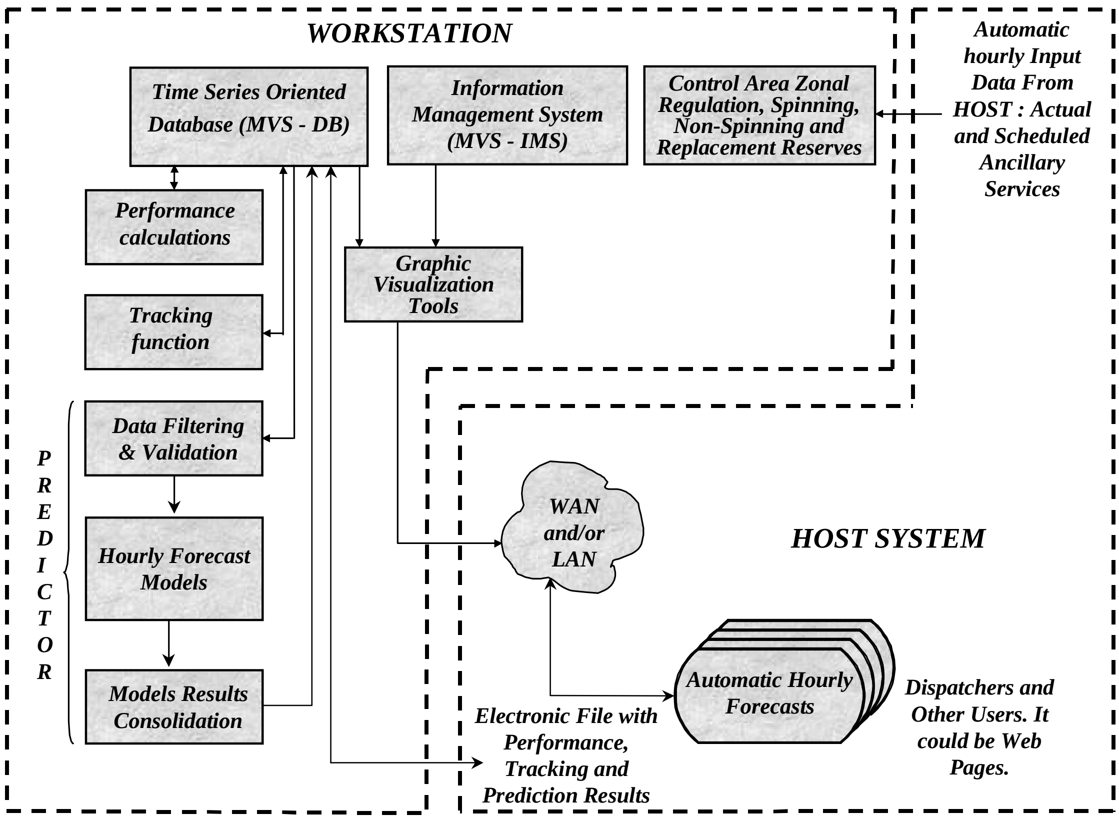
Figure 12 shows the future integration of ASPTP with a HOST input / output system. Automatically, hourly, using data from the HOST SCADA or EMS systems the Information Management Subsystem will save the input data in ASPTP's Time-Series Operational Database. Then the ASPTP application shall monitor control area's performance, track, save and tag all the data and calculations, and start the predictive function. A filtering process will clean raw data. Results of the ASPTP application and the STF and LTF forecast models probabilistic predictions will be tagged and archived and taken from the database to be displayed to the System's Operators. Data flow is fully automatic without any manual interaction, except for the interaction for allowing System's Operators to override the model's forecasts for accuracy improvement purposes.

Following is the summary description of the main function blocks in Figure 12.

- Control Area Regulation Spinning, Non-spinning and Replacement Reserves. Hourly, using a PC based application, the Host's SCADA or EMS System will save data in a time series oriented database. The data archived will be the Host Control Area loads, regulation and spinning reserve.
- Information Management System (MDMS – IMS) and Time Series Oriented Database. This database will be used to store the entire ASPTP's input, filtered and output data, parameters of the models, as well as data mining queries and selected data mining results.

- Performance calculations. To verify the compliance of the Ancillary Services provided by Suppliers and Host, ASPTP application will make calculations between bids and actual deliverables for the four Ancillary Services in the Control Area.

Figure 12 – ASPTP Overall Integration with Host System



- Tracking will be the function to register all input and output data from the performance calculations and comparisons between actual and scheduled values.
- Data Filtering and Validation. To assure data quality, the application will include an input data filtering process for raw actual data.
- Hourly Forecast Models. Represents the adaptive forecast models tuned for different real time horizons and whose results will be saved in the database and presented to the System's Operators and short-term planners. The application also will allow users intervention interactively using actual incremental rates calculated and displayed by the application.
- Models Results Consolidation. Outputs of the different models will be consolidated and also archived in the time series database in order to allow Operating Authority and System's Operators to interact with these results via the Information Management System.
- Automatic Hourly Forecasts. Displays to show the various forecasts described in the output section. They can be implemented as web pages.

- WAN or LAN are Host networks that will allow having a distributed system with access to the ASPTP database from various points of the network.

APPENDIX

General Definitions from FERC Order 888, NERC Policy 10 and CAISO

Ancillary Service is an Interconnected Operations Service (IOS), identified by the U.S. Federal Energy Regulatory Commission or State/Provincial Commissions in their jurisdictional orders, that is necessary to effect a transfer of electricity between Purchasing-Selling Entities, and which a Transmission Provider must include in an open access transmission tariff.

Bulk Electric System is the aggregate of electric generating plants, transmission lines, and related equipment. The term may refer to those facilities within one electric utility, or within a group of utilities in which the transmission lines are interconnected.

Contingency Reserve is the capacity to reduce Area Control Error (ACE) to meet the Disturbance Control Standard (DCS) and other NERC and Regional Reliability Council requirements. Contingency Reserves are composed of Contingency Reserves-Spinning and Contingency Reserve-Supplemental.

Contingency Reserve-Spinning is the portion of Contingency Reserves provided from IOS resources that is:

- Generation that is synchronized to the system and capable of being fully available to serve load within ten minutes of the contingency event; or
- Load that can be fully removed from the system within ten minutes of the contingency event.

Contingency Reserve-Supplemental is the portion of Contingency Reserves provided from IOS resources that is:

- Generation that is capable of being synchronized to the system and being fully available to serve load within ten minutes of the contingency event; or
- Load that can be fully removed from the system within ten minutes of the contingency event.

Control Area is an electrical system bounded by interconnection (tie line) metering and telemetry. It controls generation directly to maintain its interchange schedule with other Control Areas and contributes to frequency regulation of the Interconnection.

Energy Imbalance is the mismatch between the energy schedule(s) at a point of receipt (POR), or point of delivery (POD), and actual metered energy flow at that POR or POD over a scheduling period.

Interconnected Operations Services (IOS) is a service (exclusive of basic energy and transmission services) that is required to support the reliable operation of interconnected Bulk Electric Systems.

IOS Supplier is an entity that offers to provide, or provides, one or more IOS.

IOS Resource is the physical element(s) of the electric system which is (are) capable of providing an IOS. Examples of an IOS Resource may include one or more generating units and controllable loads.

Load Following is the provision of generation and load response capability, including capacity, energy, and maneuverability, that is dispatched within a scheduling period by the Operating Authority.

Operating Authority is an entity that:
Has ultimate accountability for a defined portion of the Bulk Electric System to meet one or more of three reliability objectives – generation/demand balance, transmission security, and/or emergency preparedness; and
Is accountable to NERC and its Regional Reliability Councils for complying with NERC and Regional Policies; and
Has the authority to control or direct the operation of generating resources, transmission facilities, or loads, to meet the Policies.

Regulation is the provision of generation and load response capability, including capacity, energy, and maneuverability, that responds to automatic control signals issued by the Operating Authority.

Operating Reserve as defined by MORC is Regulating Reserve, plus Contingency Reserve, plus additional reserve for interruptible imports, plus additional reserve for on-demand obligations. MORC defines each of these reserve components as:

Regulating Reserve. Sufficient spinning reserve, immediately responsive to automatic generation control (AGC). The minimum amount required is the Regulating Reserve Requirement necessary to meet North American Electric Reliability Council's (NERC) Control Performance Standard.

Host Control Area should calculate regulating reserve as the sum of the 10 minute ramping ability of the generators either on AGC control and units capable of being synchronized (and placed on AGC) and loaded to a stated capability within 10 minutes. Then subtract the algebraic sum of the expected 10 minute forecasted load change, the expected 10 minute schedule variation, and current ACE requirement to meet Control performance standard (CPS1). CPS1 regulating requirements vary with each control area depending on the control strategy implemented. Each control area approaches adequacy of load forecasts differently.

Contingency Reserve. An amount of spinning reserve and non-spinning reserve, sufficient to reduce area control error (ACE) to zero within ten minutes, equal to the greater of:

(1) The loss of generating capacity due to forced outages of generation or transmission equipment that would result from the most severe single contingency (at least half of which must be spinning reserve); or

(2) The sum of five percent of the load responsibility served by hydro generation and seven percent of the load responsibility served by thermal generation (at least half of which must be spinning reserve).

The combined unit ramp rate of each control area's on-line, unloaded generating capacity must be capable of responding to the spinning reserve requirement of that control area within ten minutes.

Additional Reserve for Interruptible Imports. An amount of reserve, which can be made effective within ten minutes, equal to interruptible imports.

Additional Reserve for On Demand Obligations. An amount of reserve, which can be made effective within ten minutes, equal to on-demand obligations to other entities or Control Areas.

<u>Automatic Generation Control</u>. Each control area shall operate sufficient generating capacity under automatic control to meet its obligation to continuously match its generation and interchange schedules to its load. It shall also provide its proper contribution to Interconnection frequency regulation.

<u>Control Performance</u>. Each control area shall monitor its control performance on a continuous basis against two Standards: CSP1 and CPS2. Each control area shall achieve CPS1 compliance of 100% and achieve CPS2 compliance of 90%.

<u>Disturbance Reporting</u>. Information and experience gained from studying disturbances, which affect the operation of the interconnected power system, are helpful in developing improved operating techniques. Entities and coordinated groups of entities within the Western System Coordinating Council (WSCC) shall establish procedures and responsibility for collecting, analyzing and disseminating information and data concerning major disturbances.